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A review on sustainable power generation in Malaysia to 2030: Historical perspective, current assessment, and future strategies

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ABSTRACT

This review focuses on energy for grid-connected electricity generation for West (Peninsular) Malaysia. A historical perspective of Malaysia's energy policies and energy-related initiatives is first provided, which sets the scene for an assessment of current situation in the country. We recommend a number of sustainable options for addressing the projected energy deficits in Malaysia up to year 2030, besides meeting the drive for low carbon systems and technologies. The latter is in direct response to an announcement by the Prime Minister of Malaysia on a conditional voluntary target of 40% reduction in the emissions intensity per unit of GDP by 2020 from a 2005 baseline at the COP15 meeting in Copenhagen. Alternative strategies are suggested that promote enhanced roles for renewable energy (RE) as well as energy efficiency and conservation (EE&C) practices based on a review of past and present policies and current developments. A greater contribution of RE from biomass, biogas, hydroelectric power, and solar photovoltaic is proposed compared to the present less than 1%, in concert with continuous more widespread adoption of EE&C initiatives. Strategies are also advocated to improve coal supply reliability and security. On top of these measures, the Malaysian government is urged to moderate energy subsidies while enforcing a common energy regulatory framework that involve all relevant agencies and parties.

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1. Introduction

Malaysia is highly dependent on energy for its economic growth. As such, the availability of adequate, reliable, and affordable energy is not only critical to drive the country′s industrial and commercial developments; energy also serves as a basic utility of social needs in ensuring a desirable quality of life for the nation′s people. Hence, the evolution of Malaysia′s energy sector has followed the route of providing secure, reliable, and cost-effective energy supply besides promoting efficient utilization, advocating supply diversification, and discouraging wastage.

Guided by future power demands, there have been calls for use of nuclear energy and increased use of coal in sustaining Malaysia′s energy supply. Added to that dimension is the Prime Minister of Malaysia′s pledge of a conditional voluntary target of 40% reduction in the CO_2 emissions intensity per unit of Malaysian GDP by 2020 against a 2005 baseline, as announced at the 15th Conference of the Parties (COP 15) to the United Nations Framework on Climate Change Convention (UNFCCC) in Copenhagen, Denmark. Thus, this paper sets out to analyze through a historical perspective the effectiveness of the various energy policies and initiatives that Malaysia has adopted since 1979 until present, and how they have affected the reliability and security of energy supply. The foregoing analysis then sets the premise to support the main thrust of the paper of advocating an energy mix made up of a greater contribution from renewable energy (RE) and more widespread adoption of energy efficiency and conservation (EE&C) measures as alternatives to coal or nuclear energy in balancing Malaysia′s future energy supply and demand. The paper concludes by recommending several strategies to realize the proposed energy mix.

2. Policy drivers and legislative framework

The major thrusts of Malaysia′s energy policies have been sustainability, efficient resource utilization, environmental safeguarding, and delivery of high quality services to its stakeholders. The various initiatives undertaken by the government reflect these approaches as expounded through the policies and plans explained next [8].

The National Energy Policy 1979 was formulated with three objectives: (1) to supply adequate energy cost-effectively from indigenous non-renewable and renewable resources, yet securely by diversifying the sources; (2) to utilize energy efficiently and productively; and (3) to minimize negative environmental impacts in the energy supply chain. This policy was timely in view of the global oil crises in 1973 and 1978, in which economic growth worldwide was severely affected by the dramatic escalation of oil prices. Malaysia was not spared of these effects since it relied mainly on oil as its main energy source. It is arguable that this policy set forth the consequence of reducing our energy mix dependence on oil.

The National Depletion Policy 1980 was aimed at safeguarding the country′s finite and non-renewable petroleum resources from over-exploitation. Production control was enforced on major oilfields of over 400 million barrels of oil initially in place (OIIP) to a conservative 1.75% of OIIP that subsequently was revised to 3% in 1985 [40]. As a consequence, crude oil production was regulated to an average of 630,000 barrels per day (bpd) while natural gas to 2000 million standard cubic feet per day (mmscfd) [11,31] as strategies to prolong the reserves' lifespan for future supply security and stability.

Complementing the National Depletion Policy is the Four-Fuel Diversification Policy 1981 that was designed to reduce over-dependence on oil as the main energy source. As the name indicates, the policy called for a four-fuel supply mix consisting of oil, gas, hydro-electric, and coal for electricity generation. To the extent possible, local sources of these fuels are used to enhance supply security. This aspiration led to the National Mineral Policy 1998 that prescribes guidelines to promote more efficient utilization of locally sourced coal through improved underground mining methods, larger equipment in surface mining operations, and computerization of mine maintenance and administrative activities.

It was only in 2000 that RE was included in the country′s energy mix for grid connected power generation through the Five-Fuel Diversification Policy 2000, under the Eighth Malaysia Plan (8 MP, 2001–2005) and the Third Outline Perspective Plan (OPP3, 2001–2010). The policy recognizes the role of RE by placing it as the fifth fuel on par with oil, gas, hydro-electric, and coal for grid-connected electricity generation. In line with these efforts is the implementation of the Small Renewable Energy Power (SREP) program in 2001 to further develop RE resources for utilization in power generation. SREP developers sign a Renewable Energy Power Purchase Agreement (REPPA) with utilities purchasing RE-generated electricity from them, particularly Tenaga Nasional

Table 1
Malaysia: sequence and thrusts of energy policies and initiatives.

Year	Policy/Plan	Thrust/objective
1975	National Petroleum Policy	Ensure optimal use of petroleum resources via regulation of ownership and management of the industry including related economic, social, and environmental safeguards
1979	National Energy Policy	Achieve supply and utilization of energy resources with environmental considerations
1980	National Depletion Policy	Guard against over-exploitation and hence dependency on crude oil and natural gas
1981	Four-Fuel Diversification Policy	Strategize generation mix as based on oil, gas, coal, and hydro
1998	National Mineral Policy	Utilize locally sourced coal
2001	Five-Fuel Diversification Policy	Recognize renewables as fifth fuel in generation mix
2001	Small Renewable Energy Power (SREP) program	Encourage small private power generation projects using renewables
2009	National Green Technology Policy	Use green technologies and promote cogeneration and renewables in power generation
2010	New Energy Policy	Enhance energy security to include economic, environmental, and social considerations
2011	Renewable Energy Act	Enforce Feed-in-Tariff (FIT) scheme for RE
2011	National Biomass Strategy 2020	Recognize use of biomass waste for biofuels

Berhad (TNB), the national power utility company. SREP licensees are allowed to generate power from renewable sources, chiefly biomass and biogas from palm oil mill wastes, solar photovoltaic (PV), and biogas from municipal landfills, besides mini-hydroelectric, wind, and biofuels from municipal waste. A maximum of 10 MW power may be exported by a small RE plant (although the plant′s overall capacity may be larger) for sale to TNB via the national grid for up to 21 years [27,41].

However, outcome of the SREP program has been poor as less than 14 MW was achieved compared to the 9 MP target of 350 MW of RE [21,7]. The major obstacles identified are: (1) high subsidies for fossil fuels in contrast to the low incentives for RE-based projects; (2) high capital expenditure with long payback period and low tariff causing financial institutions and investors to shy away from RE projects [5,41]; (3) long negotiations involved in REPPA with stringent conditions; and (4) uncertain biomass price and availability as fuel for the long term. Despite its low uptake, SREP has served to reaffirm the government′s commitment towards developing RE as the fifth fuel. At the same time, it reasserted the objectives of OPP3, which called for "… better management, utilization as well as seeking out new sources of renewable energy."

The National Green Technology Policy 2009 takes cognizance of the need for better and more efficient use of technologies that are benign to the environment such as adoption of biomass-based cogeneration technology and use of RE for power generation as well as manufacture and use of green products for diverse applications. The policy also provided a roadmap for the transition towards a low carbon economy by striking a balance between EE&C and environmental protection. Moreover, the so-called green market opens up vast business opportunities in the form of green buildings, environmentally-benign water and waste management practices, manufacturing processes with low carbon footprints, and transportation with low carbon emissions.

The New Energy Policy 2010, as embedded in 10 MP (2011–2015), expands the energy horizon to include economic efficiency, environmental, and social considerations while enhancing security through alternative resources. The current concerns are reflected in its five strategic pillars, namely: "… (a) initiatives to secure and manage reliable energy supply; (b) measures to encourage EE; (c) adoption of market-based energy pricing; (d) stronger governance; and (e) managing change …." (EPU, 2010). The policy once again emphasized EE&C and use of RE for power generation. More recently, the Renewable Energy Act 2011 has been enacted that establishes and implements the feed-in-tariff (FiT) system for RE-generated electricity [16].

Table 1 summarizes the sequence and thrusts of the various energy policies and strategies implemented in Malaysia.

3. National development plans

Malaysia′s economic developments have been centrally planned according to the five-year Malaysia Plans (MP) for integrated national development by [15]. The plans include infrastructure development covering energy policies, strategies, and initiatives to support the national economic development objectives as well as rural electrification to extend the basic amenity to the deprived segments of the society.

Until the two oil supply shocks of the 1970s, imported petroleum products were the predominant sources of primary energy for Malaysia′s electricity generation, supplemented by small hydroelectric power plants, with biomass-powered cogeneration plants for the palm oil and timber industries for the owners' use. Following the oil shocks, Malaysia formulated the National Energy Policy on electricity generation in 1979. The policy was subsequently complemented with other energy-related policies. The latter policies included the National Depletion Policy to optimize the extraction and use of indigenous oil and gas resources, and later the Four-Fuel Policy to diversify primary energy sources by incorporating local and imported coal for power generation.

Growing concerns over the finite fossil fuel resources and a desire to preserve the environment culminated in the formulation of the Five-Fuel Policy in 2000 to utilize biomass from palm oil mills (POM) and biogas waste from POM effluent (POME) for power generation. The policy was designed to achieve the dual objectives of eliminating the accumulating POM waste, which caused air and water pollution, by way of using them to generate grid-connected electricity; thus converting the polluting waste to a valuable commodity. Development of about 600 MW of grid-connected RE power generation capacity was envisaged by the end of 8 MP in meeting about 5% of the total energy demand by 2005.

To encourage adoption of the Five-Fuel Policy, it was supported with the SREP program that offered reasonable RE tariffs to promote financially viable investments for prospective developers. The government also granted fiscal incentives in the form of pioneer status and investment tax allowances besides import duty and sales tax waivers to facilitate development of RE projects. These initiatives were promoted with the implementation of UNDP–GEF-supported projects such as the Biomass-based Power Generation & Co-generation in the Malaysian Palm Oil Industry (BioGen) project (2002–2010) and the Malaysia Building Integrated Photovoltaic (MBIPV) (2005–2011) project.

The ongoing 10 MP (2011–2015) envisages the implementation of the New Energy Policy, in addition to continual developments of EE and RE. Fig. 1 lists the chronological sequence of energy initiatives taken by Malaysia beginning from the 4 MP (1980–1985) through to the current 10 MP (2011–2015).

4. Energy resources and reserves

Malaysia′s current energy mix of primary energy supply consists of oil, gas, coal, hydroelectric, and RE (non-hydroelectric) resources as delineated in Fig. 2. However, escalating prices of oil and gas, coupled with their finite reserves, will see coal, hydroelectric, and RE gaining increased importance for electricity generation, which is a trend observed globally ([25]). As such, this section sets out to review Malaysia′s major energy resources with Table 2 providing data on reserves and production capacity [34,33].

4.1. Crude oil and natural gas

As of 2010, Malaysia is a net energy exporter backed by proven oil reserves of 4.00 billion barrels with a reserves-to-production (R/P) ratio of 19.8 years [40]. However, the oil reserves pale in comparison to that of Saudi Arabia (260 billion barrels), Iran (138 billion barrels), and Iraq (115 billion barrels) [21]. Over the years, the geological structures associated with crude oil production have matured and likewise, the majority of the oilfields discovered either had been developed or have been in production for more than 30 years. Pending new discoveries, the remaining fields are generally lower in quality due to high carbon dioxide contents, smaller in sizes, and scattered in distribution—factors that make development of these fields costly.

On the other hand, Malaysia′s natural gas reserves of 83 trillion standard cubic feet (tscf) (as of 2010) has an R/P ratio of 38.2 years [40]. Similar to oil, the reserves are inferior compared to that of Russia (1680 tscf), Iran (1046 tscf), and Qatar (900 tscf) [21]. Although Malaysia is still a net gas exporter,

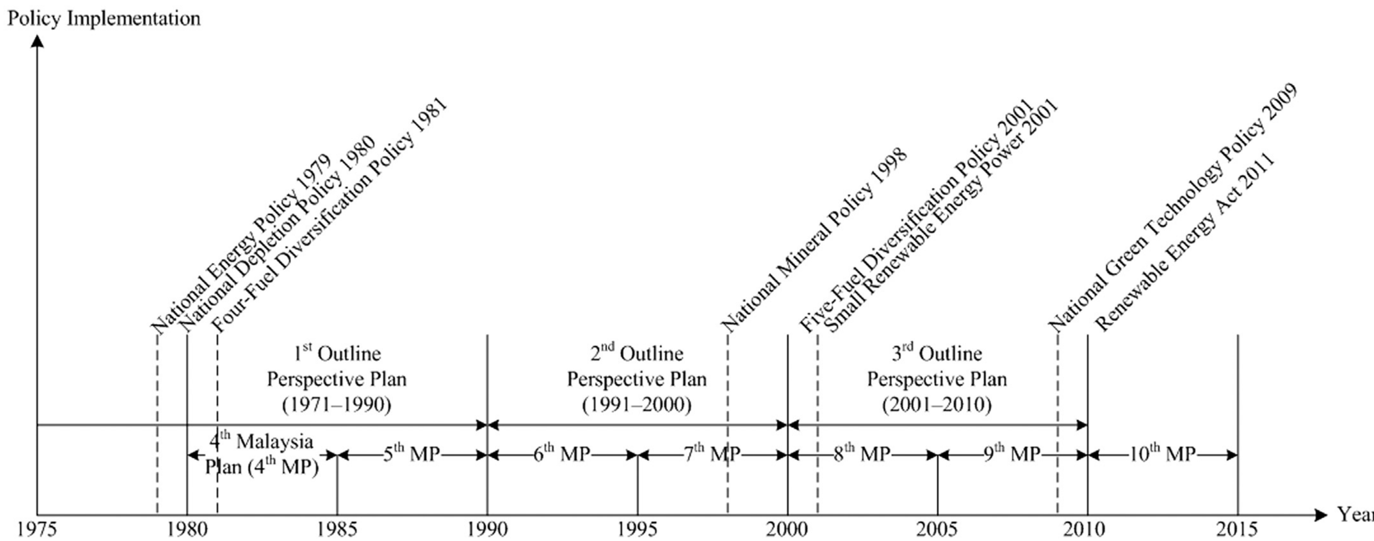


Fig. 1. Malaysia: timeline of energy-related policies and initiatives (1979–2015).

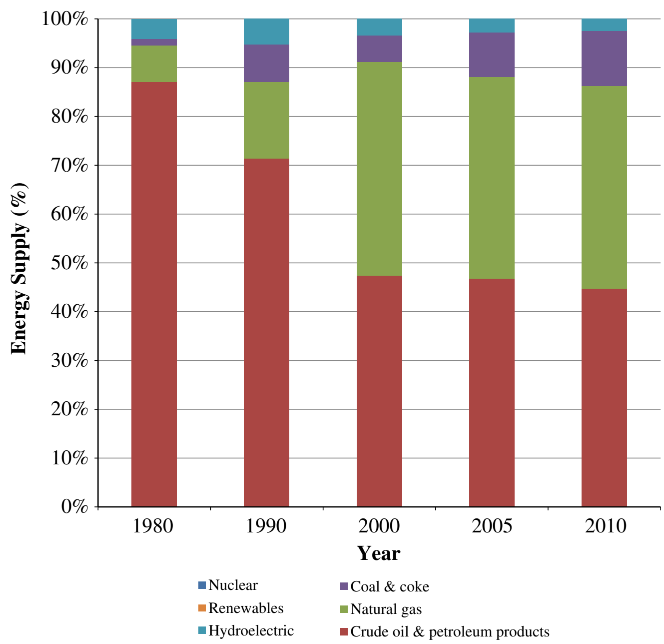


Fig. 2. Malaysia: primary commercial energy supply by source (1980–2010).

production has been declining at about 10% per annum because the gas fields are scattered in their distribution, thereby escalating their extraction cost while some may not be economically feasible.

That the oil and gas reserves are fast depleting has prompted a need to reaffirm the sustainability of their supplies. Appraisal wells will continue to be drilled in small fields offshore and in deepwater areas. Under the Economic Transformation Programme (ETP), efforts are underway to attract international oil companies for exploration activities, particularly in waters deeper than 200 m and in ultra-deep waters greater than 1 km in depth, as well as efforts to drill deeper into matured fields to increase domestic petroleum and gas production [35]. Thus, it is conceivable that for the medium and long terms, even maintaining the present level of oil production at 630,000 bpd and gas at 2000 mmscfd can prove to be challenging.

Table 2
Malaysia: energy reserves and production capacity (2009).
Source: [a]Hasan [21]; [b]Haris [19]; [b]Mohamed [31]; [b]Mohamed and Lee [30].

Energy source	Reserves (potential)	Production
Oil & condensates	5.46 billion barrels	550,000 barrels/day
Gas	88.00 tscf/d[a]	5700 mmscf/d
Coal	1843 million ton	383,000 t
Hydroelectric	20,000–22,000 MW	4000 MW
Mini-hydroelectric	500 MW	30.3 MW[b]
Biomass	1340 MW (by 2030)	39 MW[b]
Biogas	410 MW (by 2028)	4.45 MW[b]
Municipal solid waste	360–400 MW (by 2022)	5.5 MW[c]
Solar PV	(unlimited)	7.1 MW[a]
Low wind speed	(not reported)	0.2 MW[a,d]

[a] Trillion standard cubic feet/day.
[b] Total capacity under construction as of July 2009.
[c] Commissioned on 1 August 2009.
[d] Refers to TNB's wind turbine facility in Pulau Perhentian Kecil, which is a collaboration with Terengganu state government and Ministry of Regional and Rural Development [24].

4.2. Coal

Malaysia's coal reserves of 1938 million ton has an R/P ratio of 285 years [40]. The coal fields are located mainly in East Malaysia with a small portion in West Malaysia. Only a small proportion of local coal is mined for use in coal-fired power and cement plants to supplement the sizeable amount (90%) of imported coal from Indonesia (84%), Australia (11%), and South Africa (5%). Current annual coal production in Malaysia stands at about 383,000 t, a significant increase from the 65,000 t produced in 1991. Together with the imported coal, this constitutes about 27.3% of the total power generation mix. Importantly, the contribution of coal to the energy mix in the medium and longer terms is expected to grow in view of increases in both energy demands and costs of other fossil fuel types [30,26].

Although the National Mineral Policy 1998 was implemented to promote improved extraction and utilization of locally sourced coal, the production rate has yet to respond fully to the initiatives. Recently, Suruhanjaya Tenaga (ST) has awarded new licenses for two 1-GW units of supercritical coal-fired power plants at Tanjung Bin and Manjung. More licenses have been proposed by independent power producers (IPP) beyond 2015 in view of coal's relative ease of supply in the international market and its lower cost

compared to other fossil fuel types. ST has also called for bids for new coal- or gas-fired power plants in view of the expected expiry of some of the original IPP licenses from 2015 onwards, although ST is still renegotiating the existing IPP power purchase agreements for possible extension of 5 to 10 years.

4.3. Hydroelectric power

Malaysia possesses substantial hydroelectric resources; however, developing a hydroelectric power (HEP) plant is capital intensive and overwhelmingly complex, because it not only involves the design, construction, and operation of dams but also entails substantial environmental, social, and political considerations. Nevertheless, the advantages are numerous as hydroelectric is renewable, and the power generated is less affected by fluctuation in fuel prices. Hydroelectric is by far the largest renewable energy source in Malaysia. Large hydroelectric dams have been in operation in West Malaysia such as in Temenggor and Kenyir. Moreover, the ASEAN Power Grid provides a potential ready platform for harnessing use of HEP [31,21].

4.4. Miscellaneous renewable energy

Sources of non-hydroelectric RE in Malaysia include biomass, biogas, solar, wind, geothermal, as well as waste-to-energy sources. They provide alternative supply options in the overall energy mix without restriction to only a few finite energy sources. Energy generated from renewable sources is generally considered to be “green” and environmental friendly, with potential for minimizing GHG emissions that obviates costs for CO_2 emission abatement, which are otherwise necessary for fossil fuels. Besides, RE eliminates pollution from agricultural wastes because a significant proportion of RE resources are from such materials.

In view of abundant agriculture residue, sunshine, and precipitation (rainfall), the most significant sources of RE in Malaysia are biomass and biogas, solar, and small- and mini-HEP, respectively. Each of these sources involves several applications; for example, biomass includes direct combustion of plant matters to produce biofuels and syngas while solar energy includes PV conversion to electricity. In addition, wind energy contributes 0.2 MW off-grid electricity (from turbine located at the tourist resort of Pulau Perhentian island), but its availability varies with location in the country, thus arguably its development is still largely at an early stage [34]. Other RE sources that have been identified for the country include geothermal and ocean tidal energy [21,9]. Table 3 summarizes the objectives and reported status for the three major initiatives providing support and promotion mechanisms for developing RE in the country.

Currently, the installed capacity of RE stands at less than 1% (55 MW) of total power generation capacity nationwide [19]. Nevertheless, RE is expected to grow with the implementation of an FiT scheme, in which individuals can sell the power generated to utility companies such as TNB and Sabah Electricity Sendirian Berhad (SESB) at a fixed premium rate for specific period [18]. Such efforts support policies for minimizing a need for additional fossil-fuelled power plants while reducing carbon emissions at the same time.

4.5. Nuclear energy

To face the challenges posed by global warming and climate change, the government has proposed use of nuclear energy to reduce CO_2 emissions from power generation. Malaysia is reportedly one of the countries with the fastest growing rate of CO_2 emissions in the world [35]. Nonetheless, the use of nuclear power for electricity generation has remained a contentious issue, with numerous arguments for and against its use. The controversy is compounded by the March 2011 Japanese earthquake resulting in the Fukushima Daiichi nuclear plant explosion with radiation leakage, which paints a sobering picture against nuclear energy. This is not to mention the persisting unease in the public memory concerning the high profile nuclear plant accidents in Three Mile Island, USA (1979) and Chernobyl, Ukraine (1986).

Major arguments against nuclear energy include the limited raw material supply particularly uranium. The technology entails massive technical hurdles with a need for specially-trained engineers, inspectors, and personnel. This requirement is on top of the long lead time to plan, approve, build, and start-up a new reactor. The proposed development of a twin unit 1-GW nuclear power plant (NPP) by PEMANDU [35] under ETP is expected for commissioning in 2021 for the first unit (and the second in 2022 – 2023), indicating a projection of at least 11 to 12 years from pre-project stages to operation.

Furthermore, nuclear plants are costly to build. The planned 2-GW NPP for Malaysia would require a total investment of RM21.3 billion [35]. Additionally, cost over-runs are frequently associated with its construction: over-runs of 25% have been reported for similar projects in South Korea and Japan while a figure of 90% has been incurred in Finland. There are also lingering issues concerning the need for massive security to safeguard against nuclear terrorism, the potential leakage of radioactive materials, the absence of safe disposal methods for radioactive wastes that are otherwise costly, the non-guarantee of safe storage and final disposal, and the often-polarizing public opinions [10,31,17].

On the other hand, supporters of nuclear plants advocate that it is a stable and reliable source of energy. The power generated is cleaner because it emits significantly less carbon waste into the environment as compared to coal- and gas-driven generators. Moreover, Malaysia has experience in running a nuclear reactor. The Malaysian Nuclear Agency, or Nuclear Malaysia for short (formerly known as Malaysian Institute of Nuclear Technology Research (MINT)) has been operating the TRIGA PUSPATI nuclear

Table 3
Malaysia: support and promotion mechanisms for renewable energy development programs [21,22,19].

Program	Objective	Status
SREP (2001–2010)	To encourage RE-produced grid-connected electricity by small power generators (up to maximum 10 MW capacity) and allow its sale to TNB for up to 21 years	• 30 MW grid-connected power from biomass. • 2 MW grid-connected power from biogas
BioGen (2002–2010)	To demonstrate biomass and biogas grid-connected power generation projects	• 13 MW (with 10 MW for export) and 500 kW (FELDA serting) power plants are grid-connected and commissioned in July 2009 • 447 MW off-grid electricity produced by private palm oil millers
MBIPV (2005–2011)	To reduce unit cost of solar PV by 20% and increase capacity by 330% via applications in buildings	• 1.5 MW of cumulative grid-connected PV installations • PV system unit cost has dropped by about 60% (average) from 2005 to 2011

reactor since 1982. Besides, countries such as USA (104 nuclear plants), France (50), and South Korea (20) have been using nuclear power to generate electricity and can therefore be sources for experience sharing ([2]).

5. Energy for electricity generation

West Malaysia's maximum demand for electric power (see Fig. 3) for 2010 is estimated at 15,072 MW with a fuel mix comprising natural gas at 52.40%, petroleum products at 0.12% (mainly diesel), coal at 42.49%, and HEP at 4.99% (assuming negligible biomass share) (ST, 2012, pp. 10, 49, 62). Efforts have been undertaken to reduce a high dependence on gas in the fuel mix by turning more to coal (see Fig. 4), as evidenced in a decline of gas share from 59.37% in 2009 while that of coal increased from 34.51% (2009) (ST, 2011, pp. 121, 122). A similar trend is also reflected for the entire West and East Malaysia as shown in the historical and projected data to 2030 in Fig. 5.

In terms of electric power use, industrial sector is the main user accounting for 44.47% of total electricity consumption, as reported in Fig. 6. This is followed by (in decreasing order) commercial, domestic (or residential), public lighting, agriculture, and mining sectors. Demand for energy by the industrial sector is expected to be more pronounced in view of its envisaged rapid expansion under the New Economic Model (NEM) and its operative ETP in propelling Malaysia towards becoming a high income nation by 2020 [35].

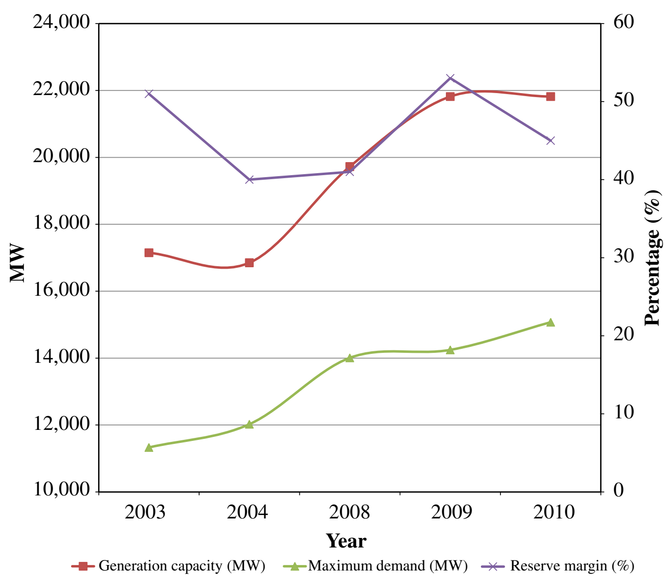


Fig. 3. West Malaysia: electricity generation statistics (2003–2010).

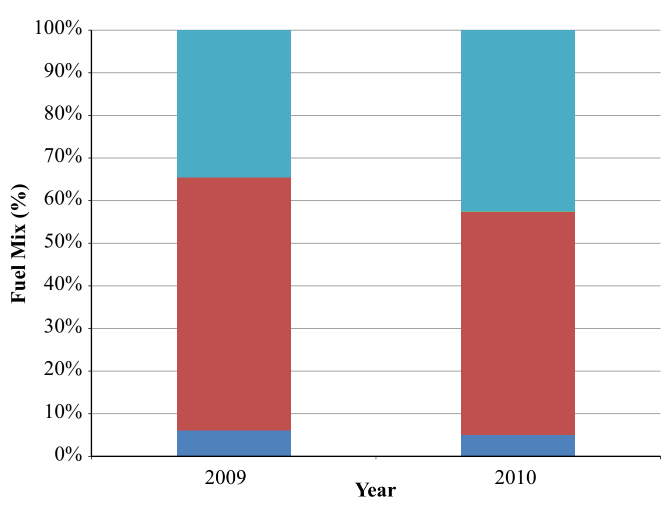


Fig. 4. West Malaysia: fuel mix for electricity generation (2009–2010).

6. Way forward

Malaysia aims to become a high-income country by 2020, in which knowledge, technology, entrepreneurship, and innovation will be central to economic growth. To support the nation's thrust, current maximum demand for electricity in West Malaysia is about 15.4 GW and is predicted to grow to an estimated 20.7 GW in 2020 [31]. Meanwhile current total electricity generation capacity stands at approximately 21.8 GW. About 4.2 GW of IPP plants will be decommissioned from 2015 to 2020, but ST has reportedly been seeking bids for about 7.3 GW for commissioning over the same period besides renegotiating possibility of extending the IPP licenses beyond the current expiry dates.

For the purpose of the subsequent analysis hereafter, let us assume that the two coal-fired plants are part of the 7.3 GW under bidding. In addition to that, the RE Act with its associated FiT regime is expected to add 2.1–3.2 GW by 2020 (which is separate from the capacity that ST has put up for bids). On top of that, the ETP under Entry Point Project 9 for EE envisages a demand reduction of 10–15% on a business-as-usual growth [36]. Assuming conservative achievement of EE and RE at 70% of their target lower-ends, demand and generating capacity are estimated to be 19.3 GW and 26.3 GW, respectively, while generating capacity will be 26.3 GW by 2020. Thus, we would still maintain a reserve margin of the order of 36%, which is well above a recommended 25% target. If EE and RE achievements are better than the conservative 70% assumption, the reserve margin would be close to 46–50%. With all the developments taken together, it warrants the consideration of whether Malaysia needs the proposed 2 GW of NPP in early 2020s.

It is noteworthy that the generation mix is expected to involve a greater share of coal, whose consumption is projected to grow at a faster rate of 9.8% per annum compared to the slower rate of oil and natural gas at 2.7% and 3% per annum, respectively. As such, Malaysia's energy infrastructure needs to be developed continuously to meet the projected demand. This will impose significant pressure on sustaining the present energy mix, especially the finite fossil fuel resources, which cannot be extended on a long-term basis into the future at current consumption rate.

Hence, there have been calls to further develop RE resources particularly in view of Malaysia's depleting fossil fuel resources. It is forecast that Malaysia will become a net energy importer starting from 2017 (assuming business-as-usual) or 2019 (assuming adoption of EE&C measures and development of RE power projects) [31]. Being a net energy importer does not mean that the country's reserves are completely drained or that Malaysia does not produce any more oil, natural gas, or coal for its own use or for export. It implies that the value of imported fossil fuels is much higher than what is exported. However, recent offshore discoveries, development, and production have improved oil and gas reserves by 2% and 3%, respectively, thus possibly delaying the transition to a net importer.

In this regard, RE is expected to play a more significant role with reduced proportion of oil and gas in Malaysia's primary energy demand. Although RE has been anticipated to assume a higher profile in the country's electricity generation mix with the implementation of the SREP program, RE's contribution hitherto

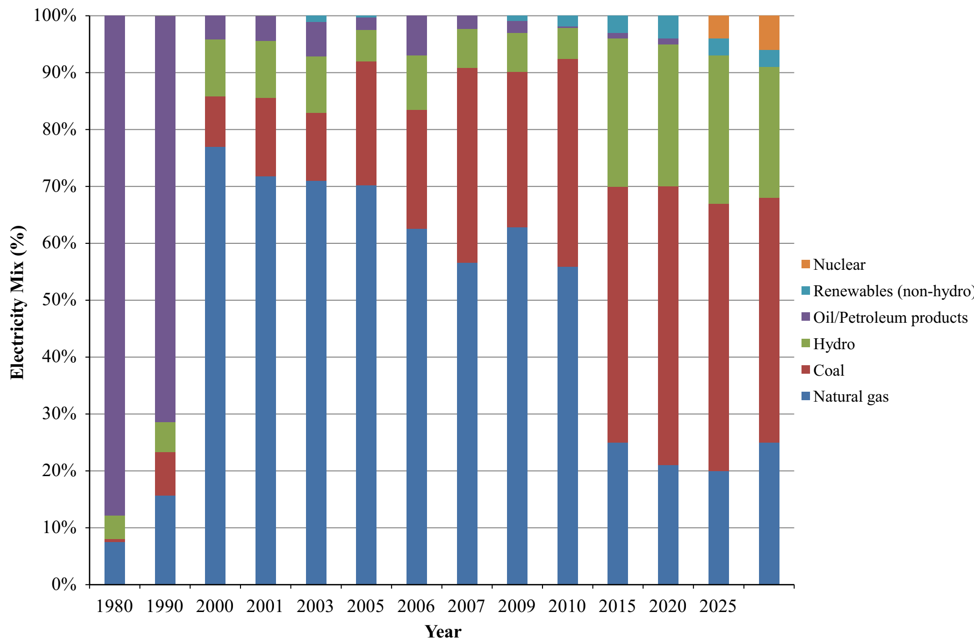


Fig. 5. Malaysia: fuel mix for electricity generation (2000–2030).

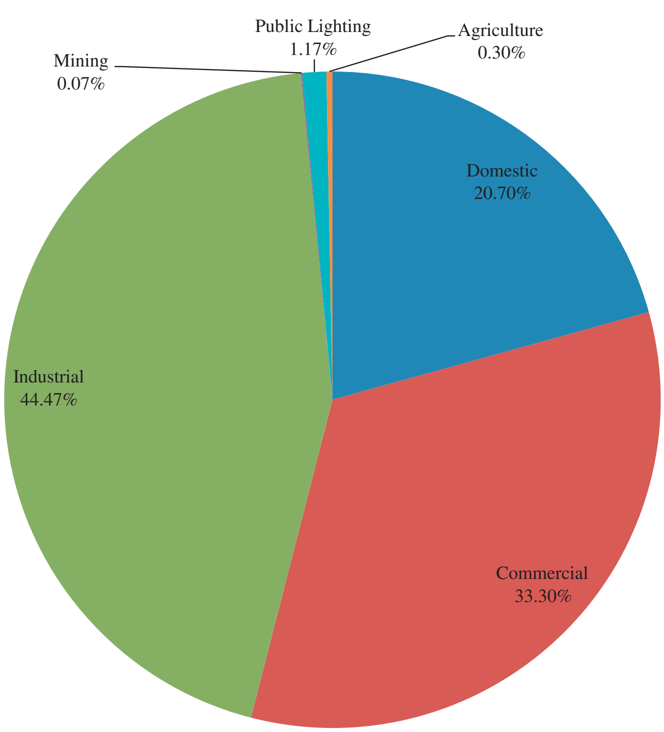


Fig. 6. Malaysia: electricity distribution by sector based on electricity sales of TNB, SESB, Sarawak Electricity Supply Corporation (SESCo), and Northern Utility Resources (NUR) Sdn. Bhd. in January–June 2010 (Energy Commission/Suruhanjaya Tenaga Malaysia, 2010).

has been dismal at less than 1% despite the financial incentives granted [32]. To boost RE′s contribution to generation mix, the recent RE Act incorporates a generous FiT scheme that allows companies and individuals to sell electricity generated from renewables to public utility companies. As such, RE′s contribution is expected to increase to 9% (about 11 TW h) by 2020 and up to 12% (17 TW h) by 2030 [19]. The targets may seem optimistic, but they are achievable and show that RE has the potential to be a major source in the nation′s future power generation equation.

Clearly, Malaysia has to consider alternative approaches to sustain its reserves and meet its energy needs for desired economic development, besides re-examining its energy mix. Potential proactive measures include adopting EE&C practices and demand side management in general. There is also a need to reassess the available electricity generation options, as discussed next.

7. Recommendations on strategies for sustainable electricity generation options

This section presents our recommendations on strategies for sustainable electricity generation alternatives and measures to year 2030 for Malaysia.

7.1. Enhancing coal supply security

Owing to its favorable price structure compared to oil and natural gas, coal will continue to be a major component of Malaysia′s energy mix and is expected to constitute over 40–45% of future energy mix. Hence it is important to have control over such a vital natural resource. Since local coal-fired power stations are not designed to run on local coal alone (blended form is possible), a strategy is to consider acquiring coal mines abroad especially in the U.S., Australia, South Africa, and Indonesia. Countries including China, India, and Japan have undertaken such measures to supplement their coal supply. Currently, there are available for sale coal mines in Australia (e.g., pits owned by Peabody Energy Corporation) and in the U.S. (e.g., Massey Energy Corporation). A Malaysian public-listed company, Jotech Holdings Berhad, has taken a stake in a coal mine in Kalimantan, Indonesia [39].

Acquisition of coal mines abroad not only ensures supply security and reliability, but it also does not incur any additional training cost since these mines are already in full operation. Therefore, the supply is instantaneous once the acquisition is complete. Moreover, despite increasing environmental constraints imposed on its production, coal asset prices are projected to increase in the future due to rising demand by energy-hungry industrialized and newly-industrialized countries. Thus a quick

decision can only serve to put one in an advantageous position. With such developments in place, coal stands to be an important component for Malaysia′s future generation mix.

7.2. Supporting renewable energy

Feasible RE resources in Malaysia for power generation primarily include biomass, biogas, mini-hydroelectric, and solar PV, while there is potential for wind energy in certain locations particularly off-grid tourist resort islands. Some measures of success have been demonstrated by the SREP program (2001–2010) and the two UNDP–GEF-supported projects, namely BioGen (2002–2009) and MBIPV (2005–2011). However, their overall achievement resulted in only 45.9 MW connected to the national grid compared to the 350 MW target for RE by 2010 [19,21]. Note that out of the 350 MW, 245 MW is aimed to be achieved from biomass consisting of 193 MW from oil palm wastes, 35 MW from municipal solid waste, 7 MW from landfill gas, and 10 MW from rice husk, whereas the remaining 105 MW is projected from mini-hydroelectric.

Under SREP, RE generated from biomass and biogas was paid RM0.21/kW h and that from mini-hydroelectric at RM0.17/kW h, whereas energy from PV was based on net metering with residential installation at up to RM0.44/kW h and commercial at up to RM0.39/kW h. In rough comparison, the prices payable for power generated from RE, except for PV, are competitive against the average rates payable for power generated from conventional fossil fuels with subsidized natural gas.

However, there is a low uptake of RE due to uncertain biomass supply besides the high capital expenditures with long payback periods involved. Such situations have caused financial institutions and investors to be apprehensive about investing in RE projects ([37]). Fortunately, the recent passing of the RE Act in 2011 has brought about some much welcome boost. First, it has incorporated the generous feed-in tariff (FiT) system for power generation in the RE industry to fast track its growth [18,19]. Second, the legislative enactment has established a regulatory framework with clearly defined roles for the regulators and power producers. Moreover, dedicated funding is available to top-up the FiT rates for renewable power producers. With FiT in place, the situation augurs favorably in achieving the 5.5% national target from RE in the generation mix as laid out in the 10th MP (2011–2015). Moving forward, Haris [19] projected the contribution of RE to the generation capacity mix to increase progressively to a high of 17% (4 GW) by 2030.

Notwithstanding the potentially fruitful consequences of the RE Act implementation, a plausible strategy as regards the challenge of ensuring continuous biomass supply is to tie in directly with palm oil mills in the country to utilize the available abundance of biomass residues for power generation and biofuel production. It is known that a current practice is to use the processing byproducts of fiber and shells as energy source for a mill itself for heat and electricity supply via combustion [43]. Such opportunity is particularly viable for mills that are connected to the electricity grid.

7.3. Adopting energy efficiency and conservation measures

Significant energy losses occur due to inefficiencies in the transmission and distribution of electric power; losses amounting to about 12% of power generated have been reported for Malaysia. As such, there avail opportunities for Malaysia to improve on its utilization through widespread adoption of EE&C measures, for example, through cogeneration and tri-generation of power and heating and cooling duties (APEC, 2011).

On a wider cross-sectoral scale, Malaysia possesses largely untapped potential for savings through EE&C measures. This condition is partly because of the marginal incentive attainable due to low electricity prices resulting from high government subsidy. Fortunately, EE&C is poised to be given a higher profile under ETP as subsidies on fossil fuels will be progressively removed. As it is, there already are many good reasons for adopting EE&C: the measures are undertaken locally, thereby enabling local participation and ensuring community resilience. They offer the low-hanging fruits for which relatively little investment is required for the substantial benefits achievable. EE&C actions also entail use of less energy and consequently, serve as a means to reduce GHG emissions and air pollution.

Similar views on the benefits of EE&C have been expressed in a [29] report which postulated that projected global energy demand growth to 2020 could be reduced significantly by enhanced EE&C. Thus, it is fair to assert that EE&C is a potent way of riding the sustainable development wave. EE&C has been touted even as the best “energy resource”. All in all, broader adoptions of EE&C are bound to provide major economic and social dividends, besides environmental benefits, often with rapid return. In this regard, the Malaysia government has played an important role by taking the lead in making its own buildings (at its Putrajaya administrative capital) and practices more energy efficient.

EE&C activities are not new in Malaysia, dating back to as early as the middle of 1980s. The 7th MP (1996–2000) promoted EE&C at the national level for the first time. The initiatives were progressively enhanced in 8th MP (2001–2005) through provision of fiscal incentives, and they have been explicitly encouraged in the 9th MP (2006–2010) via both public and private sectors' participation. As a result, numerous EE&C measures are already adopted in Malaysia, with ongoing efforts that include electrical equipment labeling program (started in 2005), energy efficiency awareness campaign, green building rating tool, and incandescent bulb phasing out (by 2014), culminating with the National Energy Efficiency Master Plan (NEEMP) [42]. Consequently, ETP envisages EE&C measures to reduce the nation′s energy bill by 10–15% by 2020 as compared to a business-as-usual scenario [36]. By a similar basis, NEEMP targets a 10% reduction in Malaysia′s electricity consumption in 2020 ([6]). Thus, it is envisaged that proper policy implementation, political leadership, and capacity building are requisites in ensuring significant contribution from EE&C initiatives.

7.4. Moderating gas subsidies

The Malaysian energy market is highly distorted: prices of petroleum products and natural gas prices as well as electricity tariffs are highly regulated by the government through subsidies. Although part of the aim is to attract foreign direct investments, subsidies have in turn led to non-efficient energy use as well as suboptimal resource allocation. As such, we advocate a need for policy-driven leadership to moderate energy subsidies in the country.

7.5. Deferring nuclear energy

Constructing an NPP is highly capital intensive. But as revealed by the foregoing analysis presented in Section 6, is NPP necessary or even warranted for Malaysia? Besides the high cost, it would also entail security concerns, not least the unwanted public perception of Malaysia′s so-called “third-world maintenance culture” that would cast further doubts about competent engineering and operation of the proposed infrastructure especially in the wake of the Fukushima tragedy. NPP would also inevitably raise concerns over health and safety issues generally associated with its construction, operation, and decommission as well as disposal of residual radioactive wastes.

Viable alternatives to nuclear power include energy resources based on renewables such as biomass, biogas, and solar (PV). Development of RE-based power generation plants under the Renewable Energy Act with FiT mechanism and adoption of EE&C practices can provide adequate alternative capacity and demand savings to defer a decision on establishing NPP, if not to substitute it altogether.

7.6. *Enforcing a common regulatory framework*

Energy issues in Malaysia currently come under the purview of several government entities, namely the Ministry of Energy, Green Technology and Water (KeTTHA), the Energy Commission (ST), the Economic Planning Unit (EPU), and the Prime Minister's Office (PMO) (with PMO primarily concerned with petroleum-based resources as vested under PETRONAS). This has resulted in issues that include: possible fragmentation of the present system concerning energy planning particularly on the supply side; energy prices not reflecting the actual costs; low energy intensity leading to loss of competitiveness; and problems with coordination and priority setting as regards decisions on EE&C practices and RE initiatives.

A regulatory framework can be effective for coordinating energy-related undertakings to drive convergence of energy requirements for the industrial, agricultural, commercial, services, and residential sectors as well as to promote use of RE, encourage EE&C practices, and minimize energy wastages. Enforcing a regulatory framework will send a strong signal to the market about the government's commitment to the energy sector. The framework will also act as a foundation on which governance principles and mechanisms are enforced to support the systematic growth of the energy and its affiliated industries. Equally, the regulatory framework will spur a critical mass to enhance use of RE and stimulate an EE&C culture.

8. Concluding remarks

Malaysia's energy mix, comprising petroleum, natural gas, coal, hydroelectric power, and renewable energy, has proven to be reliable in meeting energy needs thus far. But the situation is expected to change as Malaysia is projected to become a net energy importer before the end of the present decade. This paper recommends strategies for the roles of renewable energy (RE) as well as energy efficiency and conservation (EE&C) practices, besides enhancing the supply security of coal, as electricity generation options to year 2030. Nonetheless, successfully employing the proposed strategies require reducing the present government's subsidies on gas prices and electricity tariffs in tandem with a common regulatory framework overseeing efforts by all relevant entities involved.

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